

# IMPACT OF SPECIAL EARLY HARVEST SEASONS ON SUBARCTIC-NESTING AND TEMPERATE-NESTING CANADA GEESE

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**Abstract:** Dramatic changes in wintering distributions of Canada geese (*Branta canadensis*) have occurred over the past 50 years in eastern North America. Declines in numbers of subarctic-nesting geese wintering in southern states, and increases in numbers wintering in northern regions, have resulted in a northern shift in winter distributions. In contrast, numbers of temperate-nesting geese have increased throughout eastern North America. Management efforts to control overabundant temperate-nesting flocks have included the establishment of special early harvest seasons in September. However, the effect of early seasons on survival and harvest of subarctic-nesting populations has not been documented. Understanding the timing of migration movements and the fidelity of subarctic-nesting flocks to terminal winter refuges in the Southeast also is necessary to design early harvest seasons that target temperate-nesting flocks and protect subarctic-nesting populations. We used recoveries of marked geese to estimate survival and harvest rates before and after implementation of early harvest seasons within the Mississippi Flyway during 1976–1999. In addition, we used observations of neck-banded geese from the Southern James Bay Population (SJB-P) to evaluate the hypothesis that subarctic-nesting geese arriving prior to mid-December on several key terminal winter refuges in the Southeast (early arriving migrants) were more likely to return to those refuges in subsequent years than were migrants arriving after mid-December (late arriving migrants). September seasons during 1987–1994 were a minor source of mortality for subarctic-nesting populations and accounted for <10% of their annual harvest mortality. The effectiveness of early seasons for increasing mortality of temperate-nesting flocks varied among the states we examined and was tempered by concurrent changes in state-specific harvest regulations during the regular harvest season. For SJB-P Canada geese, annual fidelity to southeastern refuges was 10% higher for early arrivers than for late arriving geese. However, in any given year only 47–57% of the surviving geese were expected to return to the refuges the following year. Although early arriving migrants had higher survival and higher return probabilities than did late arriving migrants or geese that failed to return, numbers of geese wintering on southeastern refuges likely declined because <60% of the surviving geese affiliated with the refuges would return in a given year and because of lower survival for geese that did not return to the refuges.

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Canada geese are divided for management purposes into 8 populations in eastern North America. Six of these populations exhibit long migrations to remote breeding areas in northern Canada (subarctic-nesting), while 2 populations are classified as temperate-nesting because they breed in southern Canada and the United States. Subarctic-nesting populations primarily affiliated with the Mississippi Flyway include the Mississippi Valley Population (MVP), the Southern James Bay Population (SJB-P), and the Eastern Prairie Population (EPP), which are comprised of the interior subspecies (*Branta canadensis interior*), and the Tall Grass Prairie Population (TGPP; *B. c. hutchinsii*). Subarctic-nesting populations primarily affiliated with the Atlantic Flyway include the Atlantic Population (AP; *B. c. interior*) and the North Atlantic Population (NAP; *B. c. canadensis*).

The temperate-nesting populations are comprised primarily of the large race (*B. c. maxima*) and include the Giant Population in the Mississippi Flyway (MFGP) and the Resident Population (AFRP) in the Atlantic Flyway (Fig. 1).

Historically, the southeastern United States was the primary wintering terminus for subarctic-nesting Canada geese in eastern North America. During the past 50 years, major changes in the wintering distribution of subarctic-nesting populations have occurred in both flyways (Trost and Malecki 1985, Orr et al. 1998). Declining numbers of subarctic-nesting geese wintering in southern states, and increasing numbers wintering in northern regions, have resulted in a northward shift in their winter distributions. The resultant loss of recreational benefits associated with subarctic-nesting Canada geese in the southeastern states has become a longstanding management concern. Dwindling numbers have warranted restrictions

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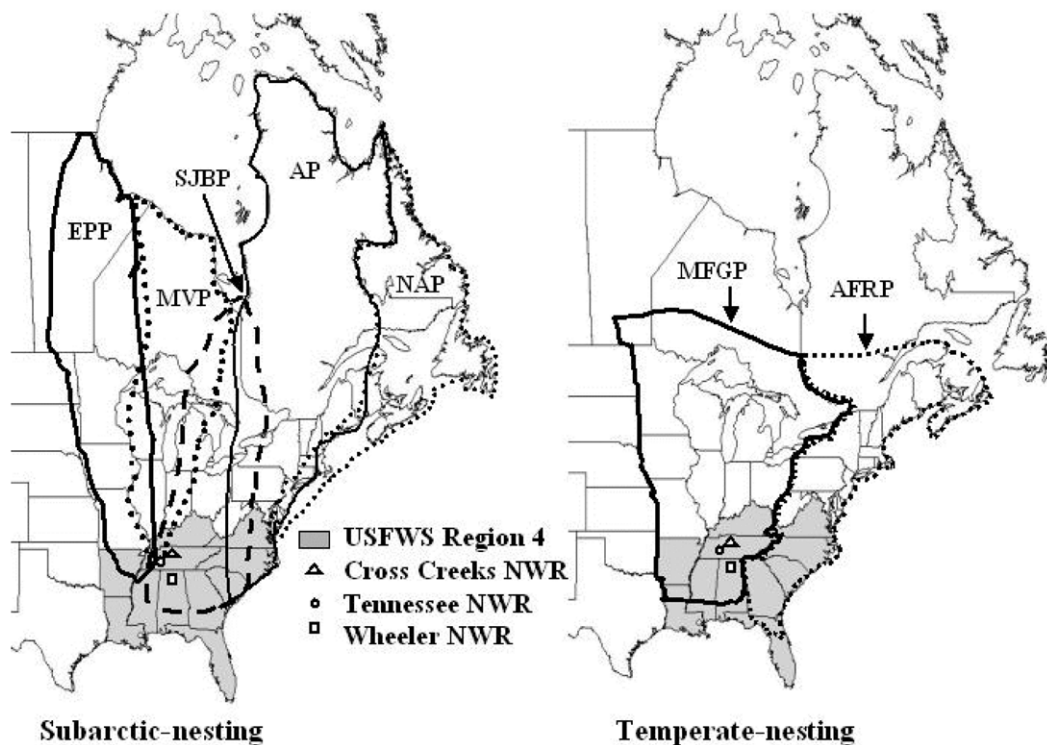


Fig. 1. Approximate ranges of Canada goose populations affiliated with the Atlantic and Mississippi Flyways (USFWS 2004). Subarctic-nesting populations include the Atlantic Population (AP), the Eastern Prairie Population (EPP), the Mississippi Valley Population (MVP), the North Atlantic Population (NAP), and the Southern James Bay Population (SJBP). Temperate-nesting populations include the Atlantic Flyway Resident Population (AFRP) and the Mississippi Flyway Giant Population (MFGP).

or cessation of sport harvest seasons on critical migration and wintering areas to protect migrant stocks and their affiliation with the south (Hindman et al. 2004, Leafloor et al. 2004).

In contrast with subarctic-nesting populations, numbers of temperate-nesting geese have increased steadily throughout the Mississippi and Atlantic Flyways. Estimated numbers of temperate-nesting geese currently exceed 1 million birds in both eastern flyways, having increased an average of 2–6% annually over the last decade (U.S. Fish and Wildlife Service [USFWS] 2004). Most temperate-nesting flocks have consistently high annual production and survival because they often occur in areas with low numbers of natural predators and because of the relative stability of breeding habitats in temperate climates. Sport harvest is the primary source of mortality for these birds, and local flocks can reach nuisance levels in regions with low harvest mortality. Management efforts to control overabundant temperate-nesting geese, while protecting subarctic-nesting geese, have focused on the regional

implementation of special early harvest seasons designed to target temperate-nesting goose populations prior to the arrival of subarctic-nesting migrants in the fall, and special harvest seasons during late winter in northern states when subarctic-nesting geese are not present (USFWS 2002). Special harvest seasons have been implemented in the Mississippi Flyway since 1983 and in the Atlantic Flyway since 1986.

The use of special early harvest seasons has increased over the past 20 years because of the continued steady increase in numbers of temperate-nesting geese. However, the effectiveness of the current criteria for implementation of a special season in protecting subarctic-nesting geese, and the cumulative impact of special seasons on the population dynamics of both subarctic- and temperate-nesting populations, have not been adequately documented. The impact that early harvest seasons have on subarctic-nesting populations is of special concern to managers in the Southeast because of the increased vulnerability of geese to harvest during the beginning of a har-

vest season and because of the variable timing of annual fall migrations. Differential timing of fall migration to southern wintering areas has been documented for segments of the EPP (Sullivan et al. 1998), MVP (Kennedy and Arthur 1974), and SJBP (Orr et al. 1998). Some studies have suggested that early arriving migrants have a higher affinity to return to terminal winter refuges in the south than do late arriving migrants (Orr et al. 1998). Understanding the timing of migration movements and the fidelity of subarctic-nesting flocks to traditional refuges in the Southeast is necessary to design early harvest seasons that target temperate-nesting flocks and protect subarctic-nesting populations affiliated with these areas.

Our objectives were to determine the impact that September harvest seasons had on survival and harvest of subarctic- and temperate-nesting populations of Canada geese affiliated with the

southeastern United States during 1976–1999, and to evaluate the hypothesis that subarctic-nesting Canada geese arriving prior to mid-December on several key wintering refuges in the Southeast (early arriving migrants), were more likely to return to those refuges in subsequent years than were migrants arriving after mid-December (late arriving migrants).

# METHODS

## Data Sources

We focused our analyses on Canada goose populations that were affiliated with southeastern states within USFWS Region 4 (Fig. 1). Historically, these states included traditional wintering areas for subarctic-nesting geese from the EPP, MVP, and SJBP in the Mississippi Flyway and the AP in the Atlantic Flyway. Data for this study were collected as part of cooperative efforts by state, federal, and provincial biologists that were designed to monitor the distribution, migration, harvest, and survival of Canada geese, 1976–1999. Canada geese affiliated with the Mississippi Flyway have been marked with leg bands since 1976. In 1980, researchers began marking subarctic-nesting geese with individually coded neck bands to improve information on harvest and winter distributions. Data on AP Canada geese were limited, therefore we restricted our analyses to populations affiliated with the Mississippi Flyway.

Subarctic-nesting Canada geese from the EPP, MVP, and SJBP were captured by researchers on the breeding grounds in northern Ontario and Nunavut during July–August 1976–1999. Flightless geese were captured during their annual molt; researchers used a helicopter to drive them into nets. Captured geese were classified by age (young-of-the-year and adult) and sex and were fitted with standard USFWS aluminum leg bands (Table 1). Some adults also were fitted with individually coded, orange plastic neck bands. Leg-band and neck-band codes were recorded from marked geese that were recaptured during banding. Nonbreeding MFGP geese often make a molt migration to subarctic-nesting breeding grounds (Zicus 1981, Lawrence et al. 1998) and can be incorrectly classified if they are captured and marked when found with subarctic-nesting geese. Geese captured on the MVP and SJBP breeding grounds were measured when banded, and we omitted marked individuals from the subarctic-nesting sample if their culmen measurement indicated they were *B. c. maxima*. We could

Table 1. Banding and recovery totals for marked Canada geese affiliated with the Mississippi Flyway, 1976–1999.

Cohort <sup>a</sup>	Years	No. banded	No. recovered
<b>Subarctic-nesting</b>			
<b>SJBP</b>			
Leg-banded adult	1976–1994	13,764	2,088
Leg-banded young	1976–1994	28,909	2,880
Neck-banded adult	1985–1999	16,869	2,626
<b>MVP</b>			
Leg-banded adult	1980–1999	5,895	919
Leg-banded young	1980–1999	43,416	5,420
Neck-banded adult	1980–1999	19,544	3,230
<b>EPP</b>			
Leg-banded adult	1985–1993	4,584	538
Leg-banded young	1985–1993	8,322	827
Neck-banded adult	1985–1993	8,637	959
<b>Temperate-nesting</b>			
<b>MFGP - IL</b>			
Leg-banded adult	1982–1999	9,074	1,732
Leg-banded young	1982–1999	32,348	7,439
<b>MFGP - IN</b>			
Leg-banded adult	1982–1999	5,224	1,278
Leg-banded young	1982–1999	10,201	2,857
<b>MFGP - MI</b>			
Leg-banded adult	1982–1999	10,479	2,212
Leg-banded young	1982–1999	30,343	6,716
<b>MFGP - MN</b>			
Leg-banded adult	1982–1999	5,448	1,398
Leg-banded young	1982–1999	15,011	4,938
<b>MFGP - OH</b>			
Leg-banded adult	1982–1999	32,328	11,041
Leg-banded young	1982–1999	64,875	20,377
<b>MFGP - WI</b>			
Leg-banded adult	1986–1999	4,150	921
Leg-banded young	1986–1999	20,081	4,602

<sup>a</sup> SJBP = Southern James Bay Population, EPP = Eastern Prairie Population, MVP = Mississippi Valley Population, MFGP = Mississippi Flyway Giant Population.

not identify molt migrants in the EPP banded sample; however, Sheaffer et al. (2004) found no difference in annual survival between breeding and nonbreeding adults from the EPP during 1984–1992.

Temperate-nesting Canada geese were captured in June–July 1982–1999 during their annual molt when ground crews could drive them into nets. Geese were classified by age and sex and fitted with aluminum leg bands. We examined data for MFGP geese from 6 states that had implemented a special early harvest season and had sufficient numbers of banded geese for survival analysis: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin (Table 1).

We used information on marked subarctic-nesting geese from 3 sources: (1) hunter reported recoveries of marked geese, (2) resightings of neck-banded geese, and (3) recaptures of marked geese during banding operations. Information on marked temperate-nesting geese came from hunter recoveries. Banding information was provided by the state and provincial agencies within the Mississippi Flyway. Observations of neck-banded geese were conducted throughout the Mississippi Flyway during September–March 1986–1999 by state, provincial, and federal personnel. Observers collected 39,199 verified observations of neck-banded SJBP geese. A verified observation was a sighting where the complete code sequence on the neck band was recorded and it matched a valid sequence in the banding file. Hunter recoveries were provided by the U.S. Geological Survey Bird Banding Laboratory (Table 1).

Early Canada goose seasons have occurred during September in the Mississippi Flyway since 1987. We identified 4 periods of interest with different levels of special early seasons: (1) prior to 1987 when there were no early seasons, (2) 1987–1989 when early seasons were restricted to portions of 3 northern states (Illinois, Michigan, Minnesota), (3) 1990–1993 when early seasons were restricted to certain counties in states north of USFWS Region 4 (Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, Wisconsin), and (4) 1994–1999 when early seasons also occurred in some counties within Region 4 (Alabama, Mississippi, Tennessee).

## Survival

We estimated survival using the band-recovery models of Brownie et al. (1985) in program MARK (White and Burnham 1999). Although resighting data provided more information per

individual than did hunter recoveries, we did not use capture–resighting models to estimate survival because we were primarily interested in comparing survival estimates before and after the implementation of special early seasons in 1987, and resighting data were not collected prior to 1986. Earlier analyses also suggested that neck-banded adults had lower survival than leg-banded adults (S. E. Sheaffer, unpublished data; Sheaffer et al. 2004), which further confounded comparison of survival estimates between populations and periods because banding effort and use of neck bands was not uniform across populations.

We created a series of band-recovery models for each cohort that included a fully parameterized global model and a series of reduced parameter models that represented plausible alternative representations of the data (Burnham and Anderson 1998). Notation for candidate models followed that of Brownie et al. (1985) where  $S$  and  $f$  denoted survival and recovery parameters for adults, and  $S'$  and  $f'$  denoted parameters for young. We used subscripts on the model parameters to denote model assumptions related to time-specificity. The global model assumed that survival and recovery rates were year-specific for neck-banded adults (model  $\{S_y, f_y\}$ ), and year- and age-specific for leg-banded adults and young (model  $\{S_y, S'_y, f_y, f'_y\}$ ).

Band-recovery data were sufficient for estimation of survival for leg-banded adults and young from the SJBP (1976–1984 and 1989–1994) and EPP (1985–1993). We were unable to estimate survival from leg-banded SJBP geese in 1985–1988 or leg-banded MVP geese in 1980–1999 due to low numbers of adults marked with leg bands in those years. Data from neck-banded adults were sufficient for estimation of survival for the SJBP (1985–1999), MVP (1980–1999), and EPP (1985–1993). Initial analyses revealed that models that assumed constant or period-specific recovery rates were never selected over models that assumed year-specific recovery rates. Therefore, all models presented in this work assumed that recovery rates varied by year ( $f_y$ ), or year and age ( $f_y, f'_y$ ). We compared the global model from each dataset with reduced parameter models that assumed constant survival over specific periods.

We examined 3 alternative parameterizations of survival for neck-banded SJBP and MVP adults:  $\{S_{p2}\}$ ,  $\{S_{p4}\}$ , and  $\{S\}$ . Model  $\{S_{p2}\}$  assumed constant survival within each of 2 periods: prior to 1987 (no early seasons), and 1987–1999 (with early seasons). Model  $\{S_{p4}\}$  assumed constant survival with-

in each of 4 periods: prior to 1987 (no early seasons), and the 3 periods with different levels of early seasons (1987–1989, 1990–1993, 1994–1999). Model {S} assumed annual survival was constant during 1976–1999. We examined the same model set for leg-banded and neck-banded EPP geese, except we substituted  $\{S_{p3}\}$  for  $\{S_{p4}\}$  because EPP data covered only 3 periods (1985–1986, 1987–1989, 1990–1993).

We examined 3 alternative parameterizations of survival for temperate-nesting geese:  $\{S_{p4}S'_{p4}\}$  and  $\{S.S'\}$  (same as for subarctic-nesting geese), and  $\{S_{p2}S'_{p2}\}$ . We modified model  $\{S_{p2}S'_{p2}\}$  for temperate-nesting geese so that the 2 periods examined reflected state-specific implementations of special early seasons (1982–1986 and 1987–1999 for Illinois, Michigan, and Minnesota; 1982–1990 and 1991–1999 for Indiana and Ohio; and 1986–1989 and 1990–1999 for Wisconsin). Some MFGP geese were harvested outside their state of banding, which could bias interpretation of results since harvest regulations differed among states. However, the effects of differential harvest regulations among states on survival of MFGP cohorts should be minor because 87% of MFGP band recoveries in September seasons, and 78% of MFGP band recoveries after September, occurred within the state of banding. In addition, 40% of band recoveries outside the state of banding occurred in a neighboring state governed by similar harvest regulations during the regular harvest season.

For each set of candidate models, we assessed the goodness-of-fit (GOF) of the global model to the data using a parametric bootstrap approach. Model selection was based on values of Akaike's Information Criteria (Akaike 1973) that were bias-adjusted to account for small sample sizes ( $AIC_c$ ). When the GOF results suggested lack-of-fit of the data to the global model and overdispersion of the data, we estimated a variance inflation factor ( $\hat{c}$ ) and based our model selection on values of the quasi-Akaike Information Criterion ( $QAIC_c$ ; Burnham and Anderson 1998). For ease of comparison we rescaled the  $QAIC_c$  values to differences in  $QAIC_c$  for each model  $i$  ( $\Delta_i$ ; Burnham and Anderson 1998). The model with the lowest  $QAIC_c$  ( $\Delta_i = 0$ ) was accepted as the most parsimonious model for the data relative to the other models considered. We compared models in a candidate set by deriving an index of relative plausibility using normalized Akaike weights ( $w_i$ ; Burnham and Anderson 1998). If a single model of a given set had an Akaike weight  $\geq 0.9$ , we used

this model to generate parameter estimates. When none of the models within a given set had a  $w_i \geq 0.9$ , parameters were estimated as a weighted average from each model using the Akaike weights. We used the  $\chi^2$  test in program CONTRAST (Sauer and Williams 1989) to compare mean survival estimates between different model sets.

## Harvest Rates

Harvest rates can be estimated from direct recovery rates adjusted by the estimated band-reporting rate (Munro and Kimball 1982). If reporting rates are constant among years, then changes in direct recovery rates can be used to index relative changes in harvest rates. We assumed that reporting rates were constant over time and estimated direct recovery rates to index changes in harvest rates for each population before and after the implementation of special early harvest seasons. We compared mean direct recovery rates among periods with different harvest regulations using the  $\chi^2$  test in program CONTRAST (Sauer and Williams 1989). We also used direct recoveries to estimate the proportion of harvest that occurred during September and during the rest of the harvest season (Oct–Feb). We estimated the proportion of the harvest that occurred in each period as the percentage of direct recoveries that occurred in each period. We did not include data past 1994 because the USFWS implemented a new system of reporting bands to a toll-free telephone number in 1995. This system likely increased reporting rates by an unknown amount, thereby violating our assumption of constant reporting rates.

## Return Rates

We used resightings of neck-banded geese to estimate return rates to 3 terminal winter refuges in the Southeast; Cross Creeks National Wildlife Refuge (NWR) in Tennessee, Tennessee NWR, and Wheeler NWR in Alabama (Fig. 1). Historically, these refuges were the primary terminal locations for wintering SJBP geese and some MVP geese in the southeast. We began by identifying all neck-banded geese that were seen at least once on 1 of the 3 refuges. We restricted this analysis to SJBP geese because relatively few MVP geese were seen on the refuges during 1986–1998. Over 95% of the observations of SJBP geese in Alabama and Tennessee occurred on refuge lands. For individuals that we identified as affiliated with 1 of the 3 refuges, 99% of the observations of those geese within Alabama and

Tennessee occurred on refuge lands. We ignored the relatively few observations off the refuges in Alabama and Tennessee because in all cases these individuals were also sighted on refuge lands within the same observation period. Encounter histories for SJBП geese were conditional on when and where they were seen within each observation year (Oct–Feb). Encounter histories included 4 possible states related to arrival status within each observation year: (1) 0 if the goose was not seen, (2) 1 if the goose was seen on 1 of the refuges prior to December 16 (early arrivers), (3) 2 if the goose was first seen on 1 of the refuges after December 15 (late arrivers), and (4) 3 if the goose was never seen on 1 of the refuges but was seen anywhere else in the flyway after December 15 (off refuge).

We used a multistate capture–resighting analysis (Hestbeck et al. 1991, Brownie et al. 1993) in program MARK to estimate state-specific transition probabilities within the Mississippi Flyway. Survival-transition probabilities,  $\phi_i^{j,k}$ , were defined as the probability that a goose alive with arrival status  $j$  in year  $i$  survives and has arrival-status  $k$  in year  $i + 1$ . Survival-transition probabilities were partitioned into 2 components,

$$\phi_i^{j,k} = S_{i,j} \psi_i^{j,k},$$

where  $S_{i,j}$  was the probability of surviving from year  $i$  to  $i + 1$  given arrival status  $j$  in year  $i$ , and  $\psi_i^{j,k}$  was the probability of arrival status  $k$  at year  $i + 1$  given that the goose was alive at  $i + 1$  and had arrival status  $j$  in year  $i$ . For example,  $\psi_{87}^{\text{early,late}}$  estimated the probability that an early arriver in 1987 returned to the refuges as a late arriver in 1988, given that it survived the year. The global model assumed that survival, resighting, and transition rates depended on arrival state and were year-specific. Goodness-of-fit was assessed using the method of Pradel et al. (2003).

## RESULTS

### Survival

The parametric bootstrap procedure indicated lack-of-fit of the global band-recovery model to data for leg- and neck-banded SJBП geese, and for leg- and neck-banded EPP Canada geese ( $P < 0.01$ ;  $\hat{c} = 1.5\text{--}2.0$ ). Band-recovery data from leg-banded MVP geese were not sufficient for estimation of survival due to low numbers of adults banded in many years. We found some evidence of overdispersion of band-recovery data from

neck-banded MVP adults ( $P = 0.05$ ;  $\hat{c} = 1.29$ ). Data from leg-banded MFGP geese also did not fit the global band-recovery models ( $P < 0.01$ ;  $\hat{c} = 1.9\text{--}2.1$ ). Model selection was based on QAIC<sub>c</sub> for all populations (Table 2).

The best approximating models to estimate survival of SJBП Canada geese assumed constant annual survival for data from 1976–1984, and annual survival for data from 1989–1994 (Table 2). Comparison between the pooled survival estimate for 1976–1984 and the average annual estimate for 1989–1994 indicated no difference in mean annual survival of leg-banded adult SJBП Canada geese before and after the implementation of special early harvest seasons in 1987 (Table 3;  $\chi_1^2 = 0.00$ ,  $P = 1.00$ ). Survival of leg-banded young SJBП geese was lower in 1989–1994 than in 1976–1984 (Table 3;  $\chi_1^2 = 7.71$ ,  $P = 0.006$ ). Values of QAIC<sub>c</sub> indicated that model  $\{S, f_y\}$  was the best approximating model for data from neck-banded adults; however, models  $\{S_{p2}, f_y\}$  and  $\{S_{p4}, f_y\}$  were within 3 QAIC<sub>c</sub> units of the top model (Table 2). We detected no difference in mean annual survival of neck-banded SJBП adults related to the special seasons in 1987–1994 (Table 3;  $\chi_1^2 = 0.65$ ,  $P = 0.418$ ).

The best approximating model to estimate survival of neck-banded MVP adults (model  $\{S_{p2}, f_y\}$ ; Table 2) indicated that their survival was about 10% lower during 1987–1999 than during the previous period (Table 3). Model  $\{S_{p4}, f_y\}$  was within 1 QAIC<sub>c</sub> unit from the top model. However, we detected no difference ( $\chi_2^2 = 0.94$ ,  $P = 0.626$ ) in survival of neck-banded adult MVP geese (Table 3) among periods with different levels of special seasons (1987–1989, 1990–1993, 1994–1999).

Band-recovery data for leg-banded EPP Canada geese were sparse in some years, and while the top model assumed that survival varied among 3 periods (1985–1986, 1987–1989, 1990–1992), model  $\{S, S', f_y, f'_y\}$  differed from the top model by <3 QAIC<sub>c</sub> units (Table 1). Band-recovery models suggested that survival of leg-banded EPP geese was highest in 1987–1989 (Table 3). The best approximating model for neck-banded adults assumed that survival varied annually  $\{S_y, f_y\}$ . Mean annual survival of neck-banded adults declined after 1986 ( $\chi_1^2 = 9.81$ ,  $P = 0.002$ ), averaging 0.802 (SE = 0.098) in 1985–1986 and 0.571 (SE = 0.073) in 1987–1992 (Table 3).

The best approximating model for band-recovery data from leg-banded MFGP geese (Table 2) assumed that annual survival varied relative to the implementation of special early seasons

Table 2. Models explaining survival of Canada geese affiliated with the Mississippi Flyway, 1976–1999. Models were ranked using the quasi-Akaike's Information Criterion (QAIC<sub>c</sub>).

Cohort <sup>a</sup>	Years	Marker	Model <sup>b</sup>	QAIC <sub>c</sub>	Δ <sup>c</sup>	w	K	Q-deviance
SJBP	1976–1984	Leg band	$S.S':f_y f'_y$	11,637.16	0.00	0.928	20	77.68
			$S_y S'_y f_y f'_y$	11,642.28	5.12	0.072	34	54.72
SJBP	1989–1994	Leg band	$S_y S'_y f_y f'_y$	2,377.18	0.00	0.586	22	18.81
			$S.S':f_y f'_y$	2,377.88	0.70	0.414	14	35.55
SJBP	1985–1999	Neck band	$S.f_y$	13,464.69	0.00	0.515	16	101.33
			$S_{p2}f_y$	13,465.37	0.68	0.367	17	100.00
			$S_{p4}f_y$	13,467.68	2.99	0.116	19	98.30
			$S_y f_y$	13,475.47	10.78	0.002	29	86.03
MVP	1980–1999	Neck band	$S_{p2}f_y$	19,971.40	0.00	0.516	22	169.30
			$S_{p4}f_y$	19,971.63	0.23	0.461	24	165.52
			$S_y f_y$	19,977.63	6.22	0.023	38	143.43
			$S.f_y$	19,991.48	20.08	0.000	21	191.38
EPP	1985–1993	Leg band	$S_{p3}S'_{p3}f_y f'_y$	6,863.55	0.00	0.745	24	55.44
			$S.S':f_y f'_y$	6,866.14	2.59	0.204	20	66.06
			$S_{p2}S'_{p2}f_y f'_y$	6,868.95	5.40	0.050	22	64.86
			$S_y S'_y f_y f'_y$	6,877.97	14.42	0.000	34	49.78
EPP	1985–1993	Neck band	$S_y f_y$	5,562.76	0.00	0.966	17	26.89
			$S_{p3}f_y$	5,570.57	7.81	0.020	12	44.7
			$S_{p2}f_y$	5,571.16	8.40	0.015	11	47.32
			$S_y f_y$	5,583.83	21.06	0.000	10	62.00
MFGP - IL	1982–1999	Leg band	$S_{p2}S'_{p2}f_y f'_y$	40,753.43	0.00	0.825	40	260.90
			$S.S':f_y f'_y$	40,756.54	3.10	0.175	38	268.01
			$S_y S'_y f_y f'_y$	40,787.83	34.39	0.000	70	235.14
			$S_{p4}S'_{p4}f_y f'_y$	41,105.45	352.02	0.000	43	606.91
MFGP - IN	1982–1999	Leg band	$S.S':f_y f'_y$	14,843.41	0.00	0.816	38	247.73
			$S_{p2}S'_{p2}f_y f'_y$	14,846.40	2.98	0.184	40	246.69
			$S_y S'_y f_y f'_y$	14,866.63	23.22	0.000	70	206.49
			$S_{p4}S'_{p4}f_y f'_y$	15,026.99	183.58	0.000	43	421.25
MFGP - MI	1982–1999	Leg band	$S_{p2}S'_{p2}f_y f'_y$	44,379.72	0.00	0.572	40	257.77
			$S.S':f_y f'_y$	44,380.30	0.58	0.428	38	262.35
			$S_y S'_y f_y f'_y$	44,411.78	32.06	0.000	70	229.53
			$S_{p4}S'_{p4}f_y f'_y$	44,541.50	161.78	0.000	43	413.53
MFGP - MN	1982–1999	Leg band	$S_{p2}S'_{p2}f_y f'_y$	20,498.41	0.00	0.836	40	256.01
			$S.S':f_y f'_y$	20,501.66	3.26	0.164	38	263.28
			$S_y S'_y f_y f'_y$	20,513.52	15.12	0.000	70	210.80
			$S_{p4}S'_{p4}f_y f'_y$	20,619.99	121.59	0.000	43	371.57
MFGP - OH	1982–1999	Leg band	$S_{p2}S'_{p2}f_y f'_y$	1,03,046.11	0.00	0.987	40	312.39
			$S_y S'_y f_y f'_y$	1,03,052.95	6.84	0.032	70	259.17
			$S.S':f_y f'_y$	1,03,075.89	29.78	0.000	38	346.18
			$S_{p4}S'_{p4}f_y f'_y$	1,03,523.67	477.56	0.000	43	783.95
MFGP - WI	1986–1999	Leg band	$S_{p2}S'_{p2}f_y f'_y$	24,213.03	0.00	0.669	32	155.80
			$S.S':f_y f'_y$	24,214.44	1.40	0.331	30	161.22
			$S_y S'_y f_y f'_y$	24,244.09	31.06	0.000	54	142.69
			$S_{p4}S'_{p4}f_y f'_y$	24,914.90	701.86	0.000	32	857.66

<sup>a</sup> SJBP = Southern James Bay Population, EPP = Eastern Prairie Population, MVP = Mississippi Valley Population, MFGP = Mississippi Flyway Giant Population.

<sup>b</sup> Model notation: S = annual survival for adults, S' = annual survival for young, f = annual recovery rate for adults, f' = annual recovery rate for young. Subscripts represent factors in the model (y = year; p2, p3, and p4 = periods with different levels of early season harvest; . = constant across years). Models for neck-banded geese include parameters for adults only.

<sup>c</sup> Model selection terms: Δ = the relative change in QAIC<sub>c</sub> from the smallest value, w = model weight, K = the number of parameters, Q-deviance = deviance/ĉ.

(model  $\{S_{p2}S'_{p2}f_yf'_y\}$ ) for geese banded in Illinois, Michigan, Minnesota, Ohio, and Wisconsin. Model  $\{S_{p2}S'_{p2}f_yf'_y\}$  had a model weight  $>0.8$  for data from Illinois, Minnesota, and Ohio. The weight for model  $\{S_{p2}S'_{p2}f_yf'_y\}$  was about 0.6 for data from Michigan and Wisconsin, with model  $\{S.S'f_yf'_y\}$  ranked second. Model  $\{S.S'f_yf'_y\}$  was ranked highest for data from Indiana, with model  $\{S_{p2}S'_{p2}f_yf'_y\}$  ranked second. Mean annual survival of MFGP geese (Table 4) declined 2–11% after the implementation of special early seasons. Declines in survival of adults were greatest in birds from Minnesota and Wisconsin (7%) and smallest in birds from Michigan and Ohio (2%). Declines in survival of young were greatest in birds from Illinois (10%) and Ohio (11%), and smallest in birds from Minnesota (3%).

### Harvest Rates

We detected no increase in direct recovery rates of SJBP Canada geese related to early harvest seasons during 1987–1994 (Table 5). Direct recovery rates of both adult cohorts and young geese SJBP Canada geese actually declined after the implementation of early seasons in 1987 ( $P < 0.01$ ). Prior to the implementation of early seasons, the only harvest of SJBP geese during September occurred in Canada. Approximately 4–5% of the harvest of adult SJBP geese occurred in September in the United States after 1987; however, this did not correspond with an increase in overall direct recovery rates. We also found no increase in direct recovery rates of EPP Canada geese during 1987–1994. We detected no change in direct recovery rates of leg-banded adults ( $P = 1.0$ ), neck-banded adults ( $P = 0.301$ ), and leg-banded young ( $P = 0.757$ ) EPP Canada geese related to special seasons (Table 5). Direct recovery rates increased for MVP Canada geese after 1986. The proportion of harvest of MVP geese that occurred in the United States during September increased from 2 to 9% for young and 5 to 7% for adult geese (Table 5). Direct recovery rates increased from 3.6 to 5.0% for neck-banded adults ( $P = 0.003$ ) and from 4.8 to 5.4% for leg-banded young ( $P = 0.047$ ).

We detected no changes in direct recovery rates of MFGP geese (Table 5) for adults and young from Indiana, Michigan, and Minnesota, and adults from Wisconsin ( $P > 0.05$ ). In contrast, direct recovery rates for adults and young from Illinois and Ohio, and young from Wisconsin, increased after the implementation of special seasons. Relative changes in direct recovery rates

Table 3. Mean annual survival estimates for subarctic-nesting Canada geese among periods with different levels of early September harvest seasons, 1976–1999.

Cohort <sup>a</sup>	Years	$\hat{S}$	SE
SJBP			
Leg-banded adults	1976–1984	0.755	0.015
	1989–1994	0.756	0.055
Leg-banded young	1976–1984	0.419	0.031
	1989–1994	0.268	0.045
Neck-banded adult	1985–1986	0.672	0.023
	1987–1999	0.693	0.011
MVP			
Neck-banded adult	1980–1986	0.788	0.019
	1987–1989	0.694	0.020
	1990–1993	0.696	0.019
	1994–1999	0.673	0.018
EPP			
Leg-banded adult	1985–1986	0.761	0.078
	1987–1989	0.914	0.054
	1990–1992	0.666	0.091
Leg-banded young	1985–1986	0.376	0.055
	1987–1989	0.585	0.058
	1990–1992	0.406	0.070
Neck-banded adult	1985–1986	0.802	0.098
	1987–1989	0.624	0.068
	1990–1992	0.517	0.052

<sup>a</sup> SJBP = Southern James Bay Population, MVP = Mississippi Valley Population, EPP = Eastern Prairie Population.

Table 4. Mean annual survival estimates for leg-banded Mississippi Flyway Giant Population Canada geese (temperate-nesting) among periods with different levels of early September harvest seasons, 1976–1999.

State of banding	Cohort	Years	$\hat{S}$	SE
IL	adult	1982–1986	0.745	0.023
		1987–1999	0.699	0.007
	young	1982–1986	0.931	0.006
		1987–1999	0.835	0.032
IN	adult	1982–1990	0.752	0.023
		1991–1999	0.711	0.011
	young	1982–1990	0.806	0.058
		1991–1999	0.743	0.046
MI	adult	1982–1986	0.693	0.010
		1987–1999	0.669	0.009
	young	1982–1986	0.666	0.028
		1987–1999	0.610	0.025
MN	adult	1982–1986	0.732	0.026
		1987–1999	0.658	0.009
	young	1982–1986	0.695	0.058
		1987–1999	0.668	0.032
OH	adult	1982–1990	0.700	0.006
		1991–1999	0.677	0.006
	young	1982–1990	0.644	0.016
		1991–1999	0.533	0.014
WI	adult	1986–1989	0.747	0.027
		1990–1999	0.676	0.011
	young	1986–1989	0.767	0.058
		1990–1999	0.731	0.040

Table 5. Direct recovery rates ( $D$ ) and the estimated proportion of harvest that occurred in Canada and the United States during September and October–February harvest seasons for Canada geese in the Mississippi Flyway, 1982–1994.

Cohort <sup>a</sup>	<i>P</i> <sup>b</sup>	No. banded	Years	$\hat{D}$	SE	Proportion of harvest			
						Sep		Oct–Feb	
						Canada	US	Canada	US
SJBP									
Leg-banded adult	<0.001	2,833	1982–1984	0.048	0.004	0.188	0.000	0.188	0.625
		4,611	1987–1994	0.029	0.002	0.144	0.050	0.076	0.731
Leg-banded young	<0.001	8,085	1982–1986	0.075	0.003	0.110	0.000	0.124	0.766
		14,450	1987–1994	0.028	0.001	0.102	0.023	0.188	0.686
Neck-banded adult	0.901	3,338	1984–1986	0.057	0.005	0.094	0.000	0.188	0.719
		8,903	1987–1994	0.058	0.002	0.079	0.044	0.109	0.770
MVP									
Leg-banded young	0.042	7,580	1982–1986	0.048	0.002	0.025	0.021	0.020	0.935
		16,362	1987–1994	0.054	0.002	0.023	0.092	0.012	0.873
Neck-banded adult	0.004	2,803	1982–1986	0.036	0.004	0.066	0.049	0.000	0.885
		8,744	1987–1994	0.050	0.002	0.029	0.071	0.005	0.895
EPP									
Leg-banded adult	1.000	963	1985–1986	0.041	0.002	0.044	0.000	0.044	0.913
		3,737	1987–1994	0.042	0.005	0.063	0.050	0.180	0.708
Leg-banded young	0.757	1,121	1985–1986	0.059	0.007	0.122	0.000	0.212	0.666
		7,806	1987–1994	0.061	0.003	0.119	0.012	0.214	0.656
Neck-banded adult	0.301	2,196	1985–1986	0.063	0.006	0.042	0.000	0.170	0.789
		6,829	1987–1994	0.056	0.003	0.080	0.020	0.109	0.791
MFGP - IL									
Leg-banded adult	0.009	1,503	1982–1986	0.033	0.006	0.000	0.018	0.000	0.982
		3,830	1987–1994	0.051	0.004	0.000	0.047	0.000	0.953
Leg-banded young	<0.001	3,835	1982–1986	0.034	0.004	0.000	0.006	0.000	0.994
		14,633	1987–1994	0.060	0.002	0.000	0.059	0.000	0.941
MFGP - IN									
Leg-banded adult	0.105	2,221	1982–1990	0.061	0.006	0.000	0.000	0.000	1.000
		370	1991–1994	0.082	0.016	0.000	0.192	0.000	0.808
Leg-banded young	0.734	5,563	1982–1990	0.085	0.004	0.000	0.000	0.000	1.000
		1,379	1991–1994	0.082	0.008	0.000	0.326	0.000	0.673
MFGP - MI									
Leg-banded adult	0.136	2,927	1982–1986	0.061	0.006	0.060	0.000	0.000	0.940
		4,040	1987–1994	0.071	0.005	0.000	0.359	0.000	0.641
Leg-banded young	0.153	5,091	1982–1986	0.078	0.005	0.006	0.060	0.000	0.934
		14,023	1987–1994	0.071	0.007	0.000	0.377	0.000	0.623
MFGP - MN									
Leg-banded adult	0.078	1,360	1982–1986	0.065	0.007	0.000	0.000	0.000	1.000
		2,237	1987–1994	0.083	0.008	0.000	0.138	0.000	0.862
Leg-banded young	0.377	2,492	1982–1986	0.087	0.007	0.000	0.000	0.000	1.000
		6,340	1987–1994	0.081	0.004	0.000	0.298	0.000	0.702
MFGP - OH									
Leg-banded adult	<0.001	16,457	1982–1990	0.059	0.002	0.000	0.000	0.000	1.000
		12,598	1991–1994	0.089	0.002	0.001	0.373	0.001	0.625
Leg-banded young	<0.001	28,534	1982–1990	0.100	0.002	0.000	0.000	0.000	1.000
		19,461	1991–1994	0.129	0.002	0.000	0.345	0.000	0.654
MFGP - WI									
Leg-banded adult	0.068	1,320	1986–1989	0.031	0.006	0.000	0.042	0.000	0.958
		904	1990–1994	0.046	0.007	0.000	0.253	0.000	0.747
Leg-banded young	0.004	3,164	1986–1989	0.043	0.004	0.000	0.019	0.000	0.981
		6,509	1990–1994	0.057	0.003	0.000	0.248	0.000	0.752

<sup>a</sup> SJBP = Southern James Bay Population, EPP = Eastern Prairie Population, MVP = Mississippi Valley Population, MFGP = Mississippi Flyway Giant Population.

<sup>b</sup>  $\chi^2_1$  test of no difference in mean direct recovery rates before and after the implementation of early harvest seasons in 1986.

Table 6. Models explaining movement and fidelity of Southern James Bay Population Canada geese, 1986–1998, relative to terminal winter refuges in USFWS Region 4. Models were ranked using the quasi-Akaike Information Criterion (QAIC<sub>c</sub>).

Model <sup>a</sup>	QAIC <sub>c</sub>	Δ <sup>b</sup>	w	K	Q-deviance
(S early <sub>y</sub> )(S late <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>y</sub> )	4,484.00	0.00	0.9886	48	1,314.17
(S early <sub>y</sub> )(S late <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>p</sub> )	4,492.92	8.92	0.0114	64	1,289.67
(S refuge <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>y</sub> )	4,510.87	26.87	0.0000	68	1,299.19
(S refuge <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>p</sub> )(ψ flyway <sub>p</sub> )	4,520.31	36.31	0.0000	85	1,272.54
(S early <sub>y</sub> )(S late <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>y</sub> )	4,531.46	47.46	0.0000	82	1,290.10
(S early <sub>y</sub> )(S late <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>p</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>p</sub> )	4,542.13	58.13	0.0000	98	1,266.43
(S early <sub>y</sub> )(S late <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>p</sub> )(ψ flyway <sub>p</sub> )	4,555.51	71.51	0.0000	118	1,236.28
(S <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>y</sub> )	4,572.01	88.01	0.0000	127	1,232.96
(S refuge <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>y</sub> )	4,586.81	102.81	0.0000	137	1,225.57
(S early <sub>y</sub> )(S late <sub>y</sub> )(S flyway <sub>y</sub> )(p early <sub>y</sub> )(p late <sub>y</sub> )(p flyway <sub>y</sub> )(ψ early <sub>y</sub> )(ψ late <sub>y</sub> )(ψ flyway <sub>y</sub> )	4,605.90	121.90	0.0000	150	1,215.55

<sup>a</sup> Model notation: S = annual survival, p = resighting probability, ψ = the probability of moving between arrival states. Super-scripts indicate arrival state: early = arrived on refuge prior to 16 Dec, late = arrived on refuge after 15 Dec, flyway = never arrived on refuge, refuge = arrived on refuge (no difference between early and late arrivals). Subscripts indicate assumptions about time dependence (y = year, p = 4 periods [1986, 1987–1989, 1990–1993, and 1994–1998], . = constant across years).

<sup>b</sup> Model selection terms: Δ = the relative change in QAIC<sub>c</sub> from the smallest value; w = model weight; K = the number of parameters; Q-deviance = deviance/ĉ.

suggest that harvest rates on adult geese from Illinois and Ohio increased by a factor of 1.5. Harvest rates for young geese were 1.3 times higher in Ohio and Wisconsin and 1.8 times higher in Illinois (Table 5) after implementation of early seasons.

The proportion of harvest that occurred in September increased after 1987 for all MFGP populations we examined. After the implementation of early harvest seasons, 19–37% of the adult harvest and 33–38% of the young harvest of MFGP geese from states whose regular harvest season affects the SJBP (Indiana, Michigan, Ohio) occurred in September. For MFGP geese from states that harvest primarily MVP during the regular harvest season (Illinois and Wisconsin), approximately 5–25% of harvest occurred in September. For MFGP geese from Minnesota, which harvests primarily EPP geese in the regular harvest season, 14% of the adult harvest and 30% of the young harvest occurred in September (Table 5).

## Return Rates

Lack of fit was indicated for the global model for SJBP geese ( $\chi^2_{154} = 282.6$ ,  $P < 0.01$ ) and the estimated variance inflation factor was  $\hat{c} = 1.83$ . Models that assumed constant survival and constrained transition parameters to be equal among years generally were preferred over models that included year-specific variation (Table 6). The best approximating model  $\{(S^{\text{early}})(S^{\text{late}})(S^{\text{flyway}})(p^{\text{early}})(p^{\text{late}})(p^{\text{flyway}})(\psi^{\text{early}})(\psi^{\text{late}})(\psi^{\text{flyway}})\}$  assumed that survival and transition rates depended on arrival state and were constant over time, and that sighting probabilities were state- and time-dependent. Annual survival for SJBP cohorts averaged 0.775

(SE = 0.037) for early arrivers, 0.681 (SE = 0.025) for late arrivers, and 0.631 (SE = 0.025) for geese that did not return to the southeastern refuges. Sighting probabilities averaged 0.693 (SE = 0.098) for early arrivers, 0.593 (SE = 0.084) for late arrivers, and 0.465 (SE = 0.037) for geese that did not return to the refuges.

The movement parameters estimated the probability of changing arrival status between 2 consecutive years for geese that survived the year. For geese that returned early to the refuges in a given year, the probability that they would return the following year as a late arriver ( $\psi_i^{\text{early, late}}$ ) was 28.5% (SE = 4.5%). The probability that an early arriving goose would not return to the refuges ( $\psi_i^{\text{early, off refuge}}$ ) was 43.3% (SE = 4.7%). In any given year, only about half of the surviving geese that were on the refuge prior to mid-December in the previous year would be expected to return. For geese classified as late arriving, the probability that they would return the following year as early arrivers ( $\psi_i^{\text{late, early}}$ ) was 12.2% (SE = 2.1%). The probability that a late arriving goose would not return to the refuges the following year ( $\psi_i^{\text{late, off refuge}}$ ) was 52.9% (SE = 3.9%). Annual fidelity to arrival status was defined as the probability of having the same arrival status for 2 consecutive years. Annual fidelity to arrival status was 28.2% for early arriving geese ( $1 - [\psi_i^{\text{early, late}} + \psi_i^{\text{early, off refuge}}]$ ) and 34.9% for late arriving geese ( $1 - [\psi_i^{\text{late, early}} + \psi_i^{\text{late, off refuge}}]$ ).

Probabilities of returning to the refuge, regardless of arrival status, can be estimated for each cohort by summing their probabilities of returning in either arrival state. For example, the return

rate to the refuges was 56.7% for early arrivers ( $\psi^{\text{early, early}} + \psi^{\text{early, late}}$ ), and was higher than the overall return rate for late arrivers (47.1%;  $\psi^{\text{late, early}} + \psi^{\text{late, late}}$ ). Once a goose failed to return to the refuges in a given year, the probability that it would return to the refuges the next year was only 21.8%: 2.0% probability of returning as an early arriver ( $\psi^{\text{off refuge, early}}$ ; SE = 1.0%) and 19.8% probability of returning as a late arriver ( $\psi^{\text{off refuge, late}}$ ; SE = 3.4%). Therefore, 78.2% of the geese that did not return to the refuge in a given year would remain off the refuges the following year.

## DISCUSSION

### Survival and Harvest

Our results suggest that early harvest seasons did not increase overall harvest or mortality rates for subarctic-nesting geese in 1987–1994. Although survival for some cohorts declined after 1986, the low incidence of band recoveries in September combined with no increases in direct recovery rates indicated that the levels of harvest during early seasons in 1987–1994 did not represent a significant mortality source for these cohorts. For example, survival of young SJBP geese was significantly lower after 1986. However, <1% of the harvest of young SJBP geese occurred during September in 1987–1994, and there was no concurrent increase in their direct recovery rates. Low survival of young SJBP geese since 1986 is primarily attributable to an increase in gosling mortality prior to fall migration due to degradation of the brood rearing habitat on Akimiski Island (Leafloor et al. 2000, Hill et al. 2003). Survival of neck-banded EPP adults also declined after the implementation of early harvest seasons in 1987. However, ≤5% of direct band recoveries from EPP geese occurred in September during 1987–1994, and we detected no change in mean direct recovery rates between 1985–1986 and 1987–1994 for both adult and young geese. Low survival of adult EPP geese after 1987 also has been attributed to an increase in nonharvest mortality (Sheaffer et al. 2004).

The implementation of early harvest seasons did correspond with a decline in survival of MVP geese, and direct recovery rates suggested that adult harvest rates increased by a factor of 1.4 (assuming no change in reporting rates). However, the temporal distribution of band recoveries indicated that the regular harvest season accounted for 90% of the harvest of MVP adults

both before and after the implementation of early seasons in 1987. Increases in mortality of adult MVP geese after 1986 therefore are primarily attributable to liberalized harvest regulations during the regular season in the 1990s.

The effects of special early seasons on MFGP geese were mixed relative to the magnitude of their effects on annual survival. Although survival of most state populations exhibited some degree of decline, the effects of early seasons on survival were confounded with changes in harvest levels during the regular harvest season. For example, declines in adult survival were smallest in states whose regular harvest seasons affect the SJBP (Indiana, Michigan, Ohio). Although 19–37% of harvest mortality for MFGP geese from Indiana and Michigan occurred in September after implementation of special early seasons, we detected no increase in direct recovery rates of birds from those states. The impact of early seasons on survival and harvest of MFGP geese in these states likely was counteracted by concurrent harvest restrictions during the regular seasons that were enacted within SJBP management zones in the early 1990s. Likewise, changes in regular season harvest regulations after 1986 in Minnesota, designed to reduce harvest of EPP geese, likely counteracted the impacts of early seasons on harvest and survival of MFGP geese from Minnesota. In contrast, while declines in adult survival were greater for MFGP geese from Illinois and Wisconsin than for those from Indiana, Michigan and Ohio, a relatively smaller proportion of the harvest of MFGP geese from Illinois and Wisconsin occurred during September. Therefore, the liberalization of regular season harvest regulations in Illinois and Wisconsin, whose regular harvest seasons primarily affect the MVP, was partially responsible for the increase in mortality of adult geese from those states.

### Return Rates

Estimated probabilities of returning in a specific arrival status could be biased if the arrival states of individual geese were misclassified. For example, early arriving geese could be classified as late arrivers if they were missed on the refuge in the early period and seen only during the late period. However, the potential for misclassification bias was not equal among the arrival classes, because a late arriving goose could never be misclassified as an early arriver. Misclassification of early arriving geese as late arrivers would negatively bias the probabilities of returning as an early arriver ( $\psi^{\text{early}}$ ).

early and  $\psi^{\text{late, early}}$ ) and positively bias the probabilities of returning as a late arriver ( $\psi^{\text{early, late}}$  and  $\psi^{\text{late, late}}$ ). The relatively high probability of sighting a goose during the early period (0.69) indicated that most of the early arriving geese were sighted during the early period; however, some misclassification likely occurred because the sighting probability was  $<1.0$ . Given that some of the early arriving geese were misclassified as late arrivers, their annual probability of returning to the refuge during the early period likely was higher than 28%.

Misclassification of early arriving geese as late could bias differential probabilities of returning to the refuge in a specific arrival state, but it would not affect the estimated probability of returning to the refuge. However, estimated probabilities of returning to the refuges could be biased if early and late arriving geese were misclassified as not having returned (i.e., if they returned to the refuges but were only sighted off the refuges). In this case, misclassification only applied to birds returning to the refuges, because geese that did not return to the refuges could never be misclassified as early or late arrivers. Misclassification of returning geese as off-refuge birds would negatively bias probabilities of returning to the refuges and positively bias probabilities of not returning to the refuges. While low estimated rates of return to the refuges are consistent with a misclassification bias, it is unlikely that misclassification rates were high enough to be the main source of the estimated differences in return rates. The probability of sighting a goose, given that it was on the refuge, was 69% for the early period and 59% during the late period. Because early arriving geese that were missed in the early period could also be sighted during the late period on the refuge, the overall probability of sighting a goose from the early arriving cohort, given that it returned to the refuges, was  $>69\%$ . The periods for sighting late arriving and off-refuge geese were identical; however, marked geese were more likely to be missed off the refuge than on the refuge, as suggested by the lower sighting probabilities off the refuge (47%). Early arriving geese had higher estimated return rates to the refuges (57%) than did late arriving geese (47%), and the lower overall return rates of late arriving geese relative to early arriving geese could be attributed to higher misclassification rates for late arriving geese. However, return rates for both arrival classes estimated that only about half of the surviving SJBP geese

that wintered on the southeastern refuges in a given year would return the following year. In addition, once a surviving goose failed to return to the refuges in a given year, the probability of returning the following year was only 22%. Given the relatively high sighting probabilities on the refuges in both periods, the estimated low rate of return for geese who wintered off the refuges could not be solely due to misclassification bias. Therefore, estimated return rates suggest that declining numbers of SJBP geese wintering on terminal refuges in the Southeast were partially due to a failure of some geese to return.

Mortality estimates ( $1 - \text{survival}$ ) from the multi-state analysis included neck-band loss because we did not correct survival estimates for marker loss. SJBP geese experienced neck-band loss rates that varied by sex and by the age of the band (S. E. Sheaffer, Cornell University, unpublished data), and survival estimates from this analysis likely were negatively biased. However, if the age classes of neck bands were randomly distributed among the arrival classes of birds (early, late, and off refuge), then relative comparisons of survival among arrival classes should be relatively unbiased due to marker loss. A more significant source of bias was the unequal intervals over which survival was estimated for the arrival classes. Survival for birds that changed arrival status from early to late or off refuge was estimated over a longer interval than was survival of the other cohorts because sampling periods for early arrivers were prior to 16 December and periods for other cohorts were during 16 December–28 February. The expected bias in survival due to unequal intervals between sample periods was a negative bias in survival of early arrivers relative to those of late arrivers and off-refuge birds. However, the survival estimate for early arrivers was  $\geq 10\%$  higher than for the other cohorts.

Higher survival for early arriving migrants could reflect restrictions in harvest regulations in northern states designed to allow passage of early migrants. Although harvest restrictions in SJBP management zones likely reduced annual mortality of early arriving migrants, they did not reduce mortality for geese that were affiliated with the southeastern refuges in years when they did not winter in the Southeast. Previous researchers have suggested that regional differences in harvest pressure and substantial mortality during long migrations have been significant factors contributing to northward shifts in distributions of wintering Canada geese (Hankla and

Rudolph 1967, Trost and Malecki 1985, Trost et al. 1986). Early arriving migrants had higher survival and higher return rates than late arriving migrants, and the increased mortality for geese that failed to return likely contributed to the loss of wintering geese in the Southeast. However, numbers of geese wintering in the Southeast have gradually declined because once a surviving goose failed to return to the refuges in a given year, the probability of returning to the refuges the following year significantly declined.

## MANAGEMENT IMPLICATIONS

Although our results indicated that early harvest seasons were not a significant source of mortality for subarctic-nesting geese in 1987–1994, early-harvest seasons have increased in intensity and geographic distribution since 1994 by 2–3 fold (USFWS Division of Migratory Bird Management). Harvest of subarctic-nesting geese does occur during September, and monitoring of early season harvests should continue to ensure that the impact on these populations continues to be minimal. However, efforts to protect subarctic-nesting geese through restrictions in early-season harvest may not be sufficient to restore numbers of wintering geese in the Southeast because these geese have relatively low annual return rates and experience higher mortality in years when they do not return to southern terminal refuges.

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